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EDITION
5

HUMAN FACTORS ENGINEERING

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READINESS/PROFESSIONALISM THRU GROWTH

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HUMAN FACTORS ENGINEERING

A SELF-PACED TEXT

LESSONS 36-40

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*****IMPORTANT NOTICE*****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

HUMAN FACTORS ENGINEERING

LESSON 36: HUMAN FACTORS AND THE MILITARY

Well, you've completed those lessons which deal with human capabilities and limitations (Lessons 1 through 20) as well as those which explain how the human fits into man-machine systems (Lessons 21-35). The final five lessons will detail how human factors concepts are applied in the military. Lesson 36 will review the major military standards and specifications which have been referenced throughout the course; a detailed bibliography is presented in your supplement beginning on Page 164.

Lesson 37 will review how human factors engineering takes place. You will also be presented an overview of the purpose and function of various military human factors organizations. In addition, some of the more prominent civilian organizations will be examined.

Lesson 38 and 39 will present you with the opportunity to apply much of the knowledge you have gained throughout the course. You will be taken through the process of acquiring a major system and you will see how the human factors specialist applies his skills.

Lesson 40 will be our equivalent to a final exam. The purpose, however, will not be to grade you, but rather to help integrate all the topics studied in the previous lessons.

Before we start, make sure you have the following documents:

AR 602-1
MIL-STD-1472
MIL-HDBK-759
MIL-H-46855
MIL-STD-1474

These publications are all important reference documents for anyone working in the human factors area within the military. We hope that by now you are at least familiar with all of them. The purpose of this lesson is to present you with greater detail concerning their use and value as human factors resource materials.

In addition, be sure you have your supplement, since there are copies of some important documents there also.

Let's first examine AR 602-1. Do you recall the main thrust of this regulation?

(GO ON TO THE NEXT PAGE)

From Page 1

(1) It sets forth DOD policy for integrating human factors engineering throughout a major revision of any materiel system. Turn to Page 51.
(2) It sets forth Army policy for integrating human factors engineering throughout the materiel acquisition cycle. Turn to Page 28.

From Page 9

(1) True, but not only this area contributes to poor performance. Return to Page 9.

From Page 14

(2) You need to be aware of the system's reliability, but today this area is more the hardware engineer's than the human factors specialist's. We don't think this is desirable; you should be concerned with reliability. We think there is a better answer. Return to Page 14.

From Page 58

(2) Doesn't it seem logical that concept exploration would precede demonstration and validation? Return to Page 58.

From Page 42

(3) Right. By dividing the number of human errors made by either the opportunity of errors or the number of equipment parts, you get an index of task and hardware complexity. This information can then be used as a guide for redesign.

In Lesson 26 we also discussed the need for training maintainers, and this training theme was expanded in Lesson 28 and 29. Several types of training methods were mentioned: on-the-job training, classroom training, computer-aided training, and team training. Which of these is most frequently used in the military?

(1) Classroom training. Turn to Page 74.
(2) On-the-job training. Turn to Page 38.
(3) Computer-aided training. Turn to Page 75.
(4) Team training. Turn to Page 84.

From Page 23

(1) The R&D team built the weapon correctly. Return to Page 23.

From Page 18

(2) Right. The last two stages are the full-scale development phase and the production and deployment stage. At the first of these stages, a firm and detailed man-machine interface should have been developed. If HFE has been done properly, we should be ready for full production. Keep in mind that there are provisions for further HFE testing in the last stage, if necessary.

Okay, back to the SALV. Let's assume that a new equipment concept has been accepted and that both the functions and the equipment necessary to meet those functions have been established. At this time you are required to help design the physical layout of the cockpit. What is the first thing you think of in such a design problem?

(1) Information processing. Turn to Page 84.
(2) Panel layouts. Turn to Page 27.
(3) Anthropometry. Turn to Page 98.

From Page 16

(3) By comparing sizes, you might think that, but if you really analyze both documents, you'll see that the statement is incorrect. Return to Page 16.

From Page 96

(3) No. Operational tests may be more difficult to conduct than the tests and evaluations of the components of the system or the system itself, but this isn't why they are listed last. Think about it again. Return to Page 96.

From Page 47

(1) Very good. Human capabilities and limitations on those capabilities have to be identified.

So, since you know the question to ask, let's see what the answers are. First, let's look at the human performance requirements. The rifleman must be able to lift the X-2001 and maintain it steadily against his shoulder for periods up to 'X' amount of time. Can he? Sure, the R&D team already checked out this aspect with anthropometric and biomechanical data.

Next, the human must be able to detect the target up to a specified number of yards. Can he? Sure, again R&D did well.

Can the human squeeze the trigger without jiggling the X-2001 to the extent that he misses the target? Yes, no problem. Proper attention has been given to the level of tension on the trigger.

Next, the operator must be able to follow the rocket's path with the naked eye. Sure, a bright flare has been added to ensure that he can track the rocket.

Okay, now the marksman must be able to sight the target area when the rocket is within range. Can he? Well, let's think about that for a second or two. The human can estimate when the rocket is in range, but he can't actually see when the rocket is on the target. Why?

(1) The marksman can't see beyond the rocket's glare. Turn to Page 70.
(2) Visual precision at this distance isn't possible, so the sighting mechanism needs to be modified so that more magnification is possible. Turn to Page 20.
(3) Visual perceptual accuracy isn’t possible when tracking an object that has the velocity of the rocket. Turn to Page 99.

From Page 12

(3) That's right. This document states, in general, the Army perspective of HFE in the acquisition cycle.

This document discussed the application of HFE to three major areas of system development:

(1) Analysis (concept exploration).
(2) Design and development (demonstration and validity).
(3) Test and evaluation (full scale development).

The major concern of analysis is the allocation of functions of men and machines. Remember, when determining this breakdown, you're concerned with human performance parameters (the information you covered in Section I of this course). On Page 2 of this document you can see that the design and development stage encompasses those areas you reviewed in Section II of this course--systems analysis, task analysis, and requirement application. Finally, test and evaluation is required to verify that the design meets human engineering and life support criteria and is compatible with the overall system requirements. Paragraph 3.1 of MIL-H-46855 details these requirements.

The use of this document is varied. Turn to Page 11 and quickly read Paragraph 6.1. As you can see, this document can be used as a means of specifying requirements for contractor support. The appendix (on Page 15) details this use. Assume that you are responsible for the development of technical data for a request for proposal (RFP) or request for quotation (REQ). You are involved with an automatic fire control system (computer controlled). Using 46855, with what requirements will the contractor comply regarding mock-up?

(1) Since the proposed contract does not involve “significant human interface for operation/maintenance/control,” the selection guide should not be used. Turn to Page 98.
(2) The contractor should use Paragraph 3.2.2.1.1 (mock-ups and models) during the demonstration and validation phase. Turn to Page 79.
(3) The contractor should use guidance provided in Paragraph 3.2.2.1.1 (mock-ups and modules) during the full scale development phase. Turn to Page 71.

From Page 10

(4) Sorry! There is a correct answer given here. Return to Page 10.

From Page 72

(2) You're right.

Recall that if equipment is designed for the average user, then only 50 percent or less of the potential users will be accommodated. Thus, adjustability is especially important when the product in question is intended for use by the different military services, or for sale in other cultures.

Incidentally, just as way of a 'memory jar,' the second principle used in applying anthropometry data is 'designing for the extreme individual.' In this case, the design features are determined by the body dimensions of individuals from one extreme or the other.

We've lingered long enough on anthropometry, and it's time to move on to other areas that play an important role in HFE. An area that is closely related to anthropometry is that of work space design, where you are concerned with accounting for the size and physical characteristics of people who are going to use the work space. Thus, if you'll recall, integrating man into his working surroundings is what work space design is all about.

Okay, let's now touch on several other factors (discussed in the first 20 lessons) that affect man's ability to adequately perform his job. For instance, in Lesson 17 a good bit of time was spent discussing how the human body reacts to temperature extremes and how this, in turn, affects performance. If you'll recall, people who work under extreme cold will develop performance deficits long before they are in danger of fatal exposure. Now, the big question is, in which aspects of performance are performance deficits most prominently manifested?

(1) Performance that relies on coordination and motor ability is primarily affected by extreme cold. Turn to Page 10.
(2) Man's reasoning ability is severely affected by extremely cold temperatures. Turn to Page 38.
(3) Man is in no way adversely affected by extreme cold. Turn to Page 73.
(4) Performance that relies on cognitive processes is severely degraded when man is exposed to extreme cold. Turn to Page 60.

From Page 16

(1) Exactly right. So, if you ever work on a team designing equipment to be used by Army personnel, you will need to be aware of the contents of MIL-HDBK-759. The principal difference between 1472 and 759 is that 1472 is terse and designed for use as specifications in contracts; 759 is tutorial and often explains why a specification is necessary.

Since MIL-HDBK-759 is so large, it will be difficult to review all of it in the space available in this lesson. But try to locate the information applicable to the following situation. A tank has been designed and is ready for operational use. However, after a few hours riding in the vehicle, the operators become sick. You're not sure of the problem but you have a general idea. Which sections of MIL-HDBK-759 should you consult to provide you guidance for solving this problem?

(1) Exhaust Systems. Turn to Page 62.
(2) Noxious Substances. Turn to Page 93.
(3) Vibration. Turn to Page 100.
(4) All of these. Turn to Page 12.

From Page 55

(3) You're partly correct, but not totally. You'd better think this through again. Return to Page 55.

From Page 62

(3) Of course, human factors testing examines how personnel integrate into the overall system, not how to select people or how to determine who is qualified to do a job.

The human factors test has two purposes:

(1) To assess what the human operator's performance contributes to the overall system performance.
(2) To identify the causes of human error or substandard performance.

Okay, we stated above that HFE tests will identify causes of human error. To what can inadequate human performance be attributed?

(1) Manpower selection problems. Turn to Page 2.
(2) Inadequate training. Turn to Page 56.
(3) Inadequate design features. Turn to Page 64.
(4) All of these can and do contribute to inadequate performance. Turn to Page 89.

From Page 10

(1) You're wrong this time. Definite performance decrement occurs during watch keeping. Return to Page 10.

From Page 7

(1) You're right. Man's coordination and motor ability are adversely affected by extreme cold.

On the other end of the continuum, heat also affects performance. Performance under conditions of heat is affected by the amount of heavy work to be done, the humidity level, and the amount of fluid lost from the body. In general, heat stress takes its greatest toll in performance in physical work activities. However, mental activities may be impaired if the temperature is above 85°F and the duration is longer than 1 hour. Otherwise, people can function adequately in heat if they must.

Besides the effects on performance of temperature extremes, various atmospheric gases can adversely affect man's ability to adequately perform a task. For instance, carbon monoxide and carbon dioxide, among others, can result in performance defects and even death, if man is exposed to too much for too long. In addition, Lesson 18 also discussed other atmospheric effects, such as radiation and atmospheric pressure, which impact on performance. The point here is that the human factors specialist must be aware of these variables and make sure they're dealt with in any system that incorporates humans.

It should also be noted that man's ability to stay alert over extended periods of time and monitor the occurrence of signals has been an important area of study for HF specialists. It has been shown that, with the passage of time, we find an increase in the number of missed or incorrectly identified signals. A key fact to be aware of is when this performance decrement is greatest. During a watch period, when would performance decrement occur?

(1) Very little decrement in performance occurs at all, unless the watch period is extremely lengthy. Turn to Page 9.
(2) The greatest performance decrement occurs during the first 30-60 minutes of watch. Turn to Page 66.
(3) Performance decrement occurs at a constant, gradual level through the entire watch period. Turn to Page 33.
(4) None of these answers are correct. Turn to Page 6.

From Page 60

(4) Right, these are all viable alternatives. Adopting one of them will put you right back into the acquisition decision phase.

Redesigning at this stage of the game is probably the best recommendation. If possible, it is best to redesign the panel so that there are no shared activities. However, you also have to think about the trade-offs of cost and mission goal completion. Maybe the physical area would have to be enlarged too much to make this recommendation effective. Redesigning so as to eliminate any confusion in a shared panel may also be an effective recommendation. It probably goes hand-in-hand with the training suggestion.

We hope you can see from the example just presented that the decisions made in the acquisition process are not cast in concrete and are made over and over again during the developmental process and life cycle of any piece of equipment.

So now you've completed all but two of the lessons in your human factors course. Congratulations! Before beginning the next lesson, read Pages 174-176 of HEL TM 29-76. Your next lesson will continue using TM 24-76. See you in Lesson 39. Turn to Page 29.

From Page 29

(1) Discomfort isn't the first consideration, and requiring written communication between crew members isn't the best way to design this system. The question about warning signals was important, however. So keep it in mind. Return to Page 29.

From Page 8

(4) Right. The difficulty could be fumes, vibration, or exhaust problems. After this lesson is finished, take the time to read what the paragraphs on noxious substances, vibration and exhaust fumes have to say about these problems.

Remember that this was just an example of the kind of problems that sometimes occur. Hopefully, a new system would not reach the production and deployment phase of the design cycle before all the possible problems have been solved.

If you'll turn to the last page of MIL-HDBK-759 you'll see a page entitled 'Standardization Document Improvement Proposal.' All mil-stds and mil-hdbks will contain a form that is similar to this one. As you work to solve human factors problems in your job, you may come up with information which is either missing from these documents or which contradicts the information found in them. It is important that these documents be corrected and updated on the basis of relevant field experience. Therefore, become familiar with this form and its use.

The next document we'll examine is MIL-H-46855, 'Human Engineering Requirements for Military Systems, Equipment and Facilities.' This document specifies what the contractor's requirements are in conducting an HFE effect. Which of the documents you've examined thus far offers the Army perspective of HFE in the acquisition cycle?

(1) MIL-HDBK-759. Turn to Page 19.
(2) MIL-STD-1472. Turn to Page 44.
(3) AR 602-1. Turn to Page 6.
(4) MIL-STD-1474. Turn to Page 65.

From Page 24

(1) Berson and Crooks were interested in performance (dependent variables), but this section does not describe how that performance was measured. Return to Page 24.

HUMAN FACTORS ENGINEERING

LESSON 38: REAL WORLD PROBLEMS, PART I

Well, here you are in the final stages of this course. We hope you've learned to identify human factors issues in systems design. In the next two lessons, we're going to give you the opportunity to practice what you've learned. You'll be taken through the development of several systems, and you will be required to decide what information is important, how to analyze the relevant data, and what to do with the results of your analyses. In these lessons you will be using HEL Technical Memorandum 29-76, 'Guide for Obtaining and Analyzing Human Performance Data in a Materiel Development Project.' So, be sure that you have this document handy.

For the purposes of this lesson, assume that you have become a leading designer of military equipment for the government of a newly formed island country called 'The United Colonies of the Atlantic (UCA).' Your defense budget is fairly large for a country the size of UCA, but quite small compared to the major world powers. Your country has an urgent need to provide offensive and defensive military capabilities. Your military leaders have issued the following requirement to you. You must produce a system which has broad capabilities to:

(1) Travel at sustained speeds of 35 mph in rough terrain.

(2) Travel from island to island at speeds of 150 mph.

(3) Conduct coastal defense missions.

In other words, you are required to develop a surface-air-land vehicle (SALV). There are 10 islands in your chain and the government has decided that five SALVS are required to defend the islands. You have a budget of $1.2 billion per year to dedicate to developing the SALVS.

So, let's see. What should your first question be? Before you begin to develop a design for the SALVS, we think you should determine whether the United Colonies really need this new system. From the recesses of your memory, you probably recall that other countries already have a defense system of the SALV type. Existing systems are limited to speeds of 20 mph on land. In addition, the old SALVS don't have undersea capabilities, only

(GO ON TO THE NEXT PAGE)

From Page 13

surface ones. A SALV capable of increased speeds and a greater range of operation will certainly make operations more efficient and effective.

So far, so good. It looks like the acquisition of a new SALV is justified. So you begin the process of system acquisition. With the completion of the MENS, you have justified the need for the acquisition of the new SALV system, and the four phases of the acquisition process have begun. In fact, you already know the performance requirements of the SALV and the overall limits to the cost of the new system you will design.

So, you move quickly to the demonstration and validation phase. This is essentially a process of determining the engineering characteristics of various designs and estimating the life-cycle costs, reliability, and maintainability aspects of the new system.

With which of these processes would a human factors specialist be most concerned?

(1) Maintainability. Turn to Page 64.
(2) Reliability. Turn to Page 2.
(3) Life-cycle costing. Turn to Page 30.
(4) All of these. Turn to Page 18.

From Page 90

(1) This answer is partially correct, but not totally. Return to Page 90.

From Page 66

(2) Quite right.

Okay, we should also mention audio displays. An important rule of thumb you learned in Lesson 10 was how to determine the proper intensity of an audio signal to use in a noisy environment. This rule of thumb was: determine the detection threshold for that signal when the condition is at its maximum noise level. Then set your audio display signal at an intensity level which is halfway between the detection level and 110 dB (you remember this now, don't you?)

Let's touch on controls, now, which we talked about in Lessons 11-13. For example, when we discussed correct positioning of controls, we noted that it is important to take into account the operator's dominant hand and foot, the possibility of accidental activation, the grouping of functionally similar controls, the priority of certain controls, and the positioning of the operator. In addition, which of the following factors would you say influence control design?

(1) Heat, weightlessness, and humidity. Turn to Page 92.
(2) Attitude, vibration, and illumination. Turn to Page 59.
(3) All of these may influence control design. Turn to Page 42.
(4) None of these answers are correct. Turn to Page 47.

From Page 21

(1) Right. Subparagraph on Seat Belts under paragraph on "Operational and Maintenance Ground/Shipboard Vehicles," specifies the requirements for seat belts in man-operated vehicles.

This last question was a little picky, but the point is this: there is a great deal of information and reference material to be found in MIL-STD-1472 (some obvious information and some not so obvious).

The next document we will review is MIL-HDBK-759, 'Military Standardization Handbook, Human Factors Engineering Design for Army Materiel.' Take a quick look through the Table of Contents (Pages IV through XIX). What impression do you get?

(1) This document expands on the use of MIL-STD-1472 in the Army. Turn to Page 8.
(2) This document provides little more than MIL-STD-1472. Turn to Page 90.
(3) If you have this document, you don't really need MIL-STD-1472. Turn to Page 4.

From Page 78

(4) You have touched on performance reliability but you need to examine the human in greater detail. Return to Page 78.

From Page 52

(2) The CCU may have been a primary one; however, it was evaluated in the advanced developmental stage. While changes can and are made at this phase, one of the systems studied was at an earlier phase and, therefore, more easily changed than the CCU. Try again. Return to Page 52.

From Page 34

(2) Well done. This was the only answer that was 100 percent correct. Hilly terrain is probably quite bumpy. Therefore, the effects of vibration and the need for appropriate restraints should be considered. We could also expect the road surface, in some cases, to be very dusty. Therefore, proper ventilation must be provided.

All the answers above contained some conditions or variables that need to be studied when a vehicle is designed for land travel. Vibration, as well as restraints, and the appropriate cushioning devices have to be investigated. Noise and visibility also are factors which impinge on the operator's performance. Toxic fumes and dust particles need to be considered as well. Would you provide individual protective gear for such pollutants, or would it be best to design the SALV to be a self-contained protective unit? These questions really can't be answered without knowing the size of the SALV, its cost, and a host of other things that you and your team members must discuss.

The SALV should also be studied in relation to its air capabilities. Remember, it can travel at speeds of 150 mph when it needs to go from island to island. The island hopping is a necessary aspect of the coastal defense system for the United Colonies of the Atlantic. In any take-off situation the G-forces wouldn't be large; let's say no more than 3+G forward acceleration. This level of acceleration can be tolerated for quite some time (even as long as 30 minutes), but for our purposes, this length of time isn't necessary.

However, you do need to take into account the effects of vibration, acceleration, deceleration, and restraining devices.

In addition to the effects and consequences of motion, is there also one other major consideration?

(1) Yes, motion sickness. Turn to Page 82.
(2) Yes, hypoxia. Turn to Page 22.
(3) No, we've covered everything. Turn to Page 91.

From Page 14

(4) Right, designing for ease of maintenance is a consideration. Hardware engineers will be most concerned with the reliability of the system and its components. Life-cycle costing will be the primary concern of the industrial engineers and accounting staff. However, you may be involved in all these processes as a team member.

In this demonstration and validation phase you need to be especially concerned with features of the equipment which will result in ease of maintenance and, most especially, with performance requirements and how they interact with ease of maintenance. So what if it can be beautifully maintained but, because of low human performance reliability, it seldom works? Can you recall what some of these features are? Think about it for a few seconds and see if you can name at least three.

We bet you remembered maintenance design features such as accessibility, ease of replacement, work space configuration, packaging, and labeling. These are all aspects of maintenance which need to be incorporated into the original design plans. Concern for these features at this early stage may result in fewer problems over the life cycle of the system.

Okay, before you finish thinking about the acquisition process, let's recall the final two stages in this process. These stages are:

(1) Task analysis and human engineering requirements. Turn to Page 37.
(2) Full scale development and production and deployment. Turn to Page 4.
(3) Simulation production and evaluation. Turn to Page 82.

From Page 50

(2) The aspirating psychrometer is not listed as equipment for measuring pollutants. This instrument is used in measuring the atmospheric environment. Return to Page 50.

From Page 12

(1) What makes you say that? MIL-HDBK-759 details quantitative data for Army materiel acquisition. We are looking for a more generalized Army perspective rather than quantitative data. Try again. Return to Page 12.

From Page 62

(1) A qualification test determines who can do a job, not the reliability or effectiveness of a system. Return to Page 62.

From Page 46

(1) Nope, this isn't really a good improvement for two reasons. Our hero still has to break into line and his walking area isn't reduced. Return to Page 46.

From Page 38

(2) While this answer is indeed a form of fidelity (physical fidelity) there is a better answer. Return to Page 38.

From Page 28

(2) Human factors engineering will, indeed, be a major consideration during the full scale engineering development phase, but you are required to initiate HFE before this time. Take another look at AR 602-1 policy. Return to Page 28.

From Page 34

(1) Recall that hypoxia is a condition which occurs because of the lack of oxygen; nothing in the situation so far has suggested that there will be a lack of oxygen. Also, acceleration effects would be likely to occur during take-off in the air-transport mode. Return to Page 34.

From Page 5

(2) Nope. Remember, the target itself doesn't need to be hit; only a detonation in the vicinity is required. Think about physiological limitations. Return to Page 5.

From Page 33

(3) That was a tough one, but you're exactly right. You've selected measurements based on the 5th percentile woman and the 95th percentile man as required.

That last question was fairly difficult. But you were prepared for it when you studied anthropometry in Lesson 6. This next one is even more difficult. You've just designed a one-man transportation vehicle (let's not specify what type). You've included a seat belt. Your supervisor says that seat belts are okay for civilian safety, but he wants to know why you've included it in your design. After researching the subject, what would you tell your supervisor about the use of seat belts?

(1) According to military standards, seat belts should always be included unless they interfere with operational requirements. Turn to Page 16.
(2) Since no mention is made of seat belts in paragraph titled "Hazards and Safety." their use is up to the designer's discretion. Turn to Page 41.
(3) Only administrative type vehicles are required to have seat belts. Turn to Page 24.

From Page 62

(2) Personnel selection testing is used to 'select' people, not to test reliability or effectiveness of a system. Return to Page 62.

From Page 73

(2) A task analysis applied to the kitchen staff may very well show how they contribute to the congestion, but that isn't the first thing you need. Essentially, this is a link analysis problem which means you first want to study traffic flow patterns. What do you need for that? Return to Page 73.

From Page 17

(2) Very good. In an island-hopping vehicle like SALV, you probably won't run into any hypoxic conditions. However, it is best to be prepared for this eventuality in any flying machine. Also, if the SALV has submarine capabilities, this condition would be a big consideration for your human factors team.

Okay, let's assume that the SALV has been completely designed at this point. Now, in addition to the SALV defense system, you are also involved in the appropriate training of weapons system personnel. Just this very day, you've received a phone call from an agitated infantry field unit commanding officer. It seems that the R&D team had developed a new small rocket launcher. The size and shape of the gun resembled an M-16 rifle. However, this gun (the X-2001) was designed to shoot a small rocket at the designated target. To aid the gunner in sighting the rocket as it approached the target, a small phosphorescent flare was attached to the back of the rocket casing. When the rocket was launched, the gunner could track its path by watching the flare. When the rocket approached the target zone, the infantryman could press his detonate button and the mission would be accomplished. In effect, the marksman didn't have to actually hit the target, just make sure his shot was within the appropriate range.

Well, the design team was highly pleased with the capability and reliability of the weapon. An on-site testing was arranged, and the commanding officer selected his best marksmen to test the X-2001. To everyone's amazement and consternation, no targets were destroyed, even though the testing session was repeated several times.

The R&D team maintained that the fault was not in the weapon itself; it was balanced, perfectly aligned, and the ammunition was fine. They suggested that the problem was caused by the low level of expertise of the marksmen, and a more sophisticated shooting team was brought in to prove that point. Again a testing session was arranged and again no hits. Eventually, it was decided that increased training was required for the X-2001 user population. Somehow, different types and amounts of training were required for the M-16 and the X-2001. It was at this point that the commanding officer called you.

(GO ON TO THE NEXT PAGE)

From Page 22

After explaining all the problems with the X-2001, the commanding officer stated, 'we need this weapon; it must be used. Find a training program to teach my men how to use the X-2001 effectively!'

Okay, what do you do? What is the first step?

(1) See if the users' anthropometric measurements are appropriate to the X-2001 dimensions. Turn to Page 3.
(2) Design a training program to provide increased practice times for the users. Turn to Page 27.
(3) Determine whether a training program is, in fact, needed. Turn to Page 47.

From Page 86

(2) Well, this is correct, but there are other correct suggestions as well. Return to Page 86 and select another answer.

From Page 52

(4) Right, when your evaluation and tests are conducted at the concept exploration phase (old name experimental prototype/breadboard), changes are easier to make than at later stages of system development.

If you look at the contents listed on Page 1 of TM 29-76, you will notice that both the mission control station and the CCU were evaluated in similar ways. First, the human factors team reported what and who was being studied. Take the control station, for example. This information is presented in Pages 49-63. The pilots' and copilots' tasks and subtasks are reported, the testing environment is explained, and the tested subjects are described, as is the equipment and clothing worn. This type of information may be familiar to you from your experimental design lessons. In effect, the 'test preparation' sections of these studies are similar to which of the following experimental controls?

(1) Dependent variables. Turn to Page 12.
(2) Independent variables. Turn to Page 55.
(3) Subject- and situation-relevant variables. Turn to Page 60.
(4) Subject- and sequence-relevant variables. Turn to Page 93.

From Page 21

(3) That answer is only partially correct. Reread Section 5.12.2.7 a little more closely. Return to Page 21.

From Page 78

(2) No! You're getting your terms confused. Return to Page 78.

From Page 50

(3) Right. The universal gas tester will detect CO, CO_2, and other gases. The monitoring gas sampler will measure dust particles. Keep up the good work.

Well, we've come to the end of Lesson 37. This lesson has focused on ways and reasons for testing and/or evaluating the system or subsystem. The next two lessons will put you into the real world and will guide you in making human factors decisions in 'on-the-job' situations. See you there, in Lesson 38: Real-World Problem, Part I. Oh yes, TM 29-76, which you have used before, will also be used in Lesson 38. Prior to starting that lesson, it would be a good idea to review this document. Turn to Page 13.

From Page 52

(1) CCU was at the brassboard phase of development, but the mission control station was at breadboard phase of development (new terms concept exploration ad demonstration and validation, respectively). Now think about when change is easier to make and, therefore, most likely. Return to Page 52.

From Page 39

(2) Your answer is incorrect. Return to Page 39.

From Page 72

(4) You are incorrect. Only one correct answer is presented. Return to Page 72 and choose another answer.

From Page 58

(4) There is a correct answer provided. Return to Page 58.

From Page 50

(1) Take a closer look at Table 2-2 so you can select the correct answer. Return to Page 50.

From Page 4

(2) This is an important consideration for human factors engineering, but in this case, it would only be considered after you have designed the cockpit so that the operators fit into it. Return to Page 4.

From Page 23

(2) If the people used in the testing were already expert marksmen, how would increasing the practice times with the X-2001 solve the problem? Return to Page 23 and select another answer.

From Page 67

(1) High face validity is probably a good thing to have in any experiment, but this is not the idea behind having an externally valid experiment. Return to Page 67.

From Page 2

(2) Exactly right. AR 602-1 'implements the requirement to integrate human factors engineering (HFE) throughout the materiel acquisition cycle.'

It is a document with which you need to be intimately familiar. AR 602-1, 'Human Factors Engineering Program,' is divided into four sections. The introductory section (Paragraphs 1 and 2) defines the purpose of the regulation and the meaning of HFE in the Army. The next section (Paragraph 3) details the objectives of the Army's HFE program. The third section (Paragraph 4) is quite detailed, and it explains the Army's HFE policy and how it applies to all phases of the acquisition cycle. The fourth major section (Paragraph 5) delineates major responsibilities for human factors engineering programs within the Army.

Before discussing the next document, we would like you to answer the following question. According to AR 602-1, when in the life cycle of a system will HFE be initiated?

(1) Simulation phase. Turn to Page 68.
(2) Full scale engineering development phase. Turn to Page 20.
(3) Concept exploration phase. Turn to Page 36.

From Page 96

(2) The components of a system are important, but surely they have no more importance than the system itself or its operation. Return to Page 96.

From Page 88

(4) Look a little more closely, two of these answers are close and one is way out of line. Remember, we're looking for the instance in which the use of systems analysis is most important. Return to Page 88.

LESSON 39: REAL WORLD PROBLEMS, PART II

Here we are on the final informational lesson of your Human Factors Engineering Course. In this lesson you will continue the involvement you began in Lesson 38 with the United Colonies of the Atlantic and their defense system.

It now looks like the SALV will become a reality. You and the other members of the design team have considered how the SALV fits into the overall defense system. The global mission requirements and functions for the system and its subsystems have been defined. Because of your valuable contributions so far, your team was also required to ensure that human factors principles are used in the construction of the SALV cockpit prototype. So, let's consider some other details of the cockpit design.

On Pages 169-172 of the Supplement you will find a human factors checklist[1] which we may view as a list of information that you should remember from your first 20 lessons. Take a look at the checklist. Each item can help focus your thinking in a particular area. For example, let's take item 1. This is the only one which addresses the issue of noise. If you had to check 'yes' to item 1, what others questions should you be asking?

(1) Is the environment too discomforting? Can a warning signal be heard? Can communication be written instead of oral? Turn to Page 11.
(2) Is the noise level loud enough to cause hearing loss? Is speech being masked by the present noise level? How can this problem be solved? Turn to Page 86.
(3) Is the noise due to too many audio displays? How can the engine be redesigned so the noise can be most effectively muffled? Turn to Page 35.

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[1]This checklist was taken from a Human Engineering Laboratory publication, TM 29-76, "Guide for Obtaining and Analyzing Human Performance Data in a Materiel Development Project."

From Page 86

(3) Very good. You should (1) test the new signals for detectability; (2) make sure the new signal isn't already in use for other purposes; (3) use frequencies between 500 and 3,000 Hz; and (4) keep both the old and new systems in effect until people become accustomed to the new one.

So here we are back to our real-world problem. You've thought about the auditory characteristics of the cockpit; now, let's think about the visual displays. Which of the following is one of the first things you want to ensure?

(1) Be sure primary displays and emergency displays are placed where they can be seen easily. Turn to Page 81.
(2) Space the primary displays evenly between the pilot and chief navigator so both have access to these. Turn to Page 71.
(3) Ensure that primary displays are located at least 60 degrees below the horizon so as to be well within the normal line of sight. Turn to Page 99.

From Page 90

(2) This answer is partially correct, but not totally. Return to Page 90.

From Page 14

(3) You may be part of the costing team, but you will be concerned with other things as well. There is a better answer. Return to Page 14.

From Page 73

(1) You are correct. The diagram, by itself, will not show typical traffic flow. That has to be established by observation. You can use the diagram of the facilities to record your observations or the typical flow pattern of user traffic. This pictorial representation will be of value in recognizing and documenting some of the most serious congestion spots.

Figure 38.1 presents the diagram of the serving area. The arrows on this figure represent the path of a customer who ordered a hamburger and french fries, and who then also obtained a small salad, dessert, and milk. The darkened circles in the diagram represent other customers who either are waiting to be served, or who are standing in line to pay for their purchases.

Figure 38.2 shows a variety of entry paths that customers could take. Of course there are others, but we think you get the general idea.

As you look at this diagram, keep in mind that your mission is to diminish the traffic congestion, not to come up with a better design for a new cafeteria. You won't be able to solve the problem totally, just minimize it.

As the figures indicate, customers can enter the cafeteria serving area from any one of three entryways. These doorways also serve as exits, although only two of them are official customer exits; only two of them are manned by cashiers. In looking at the diagram what do you think is the major cause of customer congestion?

(1) The slow replacement of depleted food items. Turn to Page 87.
(2) The number of exits and entries to the serving facility. Turn to Page 94.
(3) Lack of organization of the food items and groupings. Similar foods, such as salads, are not grouped together. Turn to Page 45.

From Page 98

(3) An REP is a 'Request For a Proposal' issued by some agency which needs work done. An ROC is a 'Required Operational Capability' statement that is required by the Army during the system acquisition process. Return to Page 98 and choose another answer.

From Page 53

(4) You are incorrect in assuming that no correct answers were provided. Return to Page 53 and select another answer.

From Page 58

(3) Your answer is incorrect. Your phases are out of order. Return to Page 58.

From Page 37

(1) Exactly right.

The last major section of MIL-STD-1472, Detailed Requirements, presents detailed requirements for human factors engineering. These requirements cover 14 major areas of system design. They are:

(1) Control/display integration.
(2) Visual display,
(3) Audio display.
(4) Controls.
(5) Labeling.
(6) Anthropometry.
(7) Ground work space design.
(8) Environment.
(9) Design for maintainability.
(10) Design of equipment for remote handlings.
(11) Small systems and equipment.
(12) Operational and maintenance ground/shipboard vehicles.
(13) Hazards and safety.
(14) Aerospace vehicle compartment design requirements.

If you were designing a control which had to be operated from the kneeling position, it would be necessary for you to consider the kneeling height of the operators who would work at that work station. Based on the specific requirements given in MIL-STD-1472, which of the following ranges of 'kneeling heights' would you use in your design? (use subparagraph titled "Common Working Positions" under paragraph titled "Ground Workspace Design Requirements.")

(1) 48.0-53.9 inches. Turn to Page 44.
(2) 48.2-54.4 inches. Turn to Page 46.
(3) 45.1-53.9 inches. Turn to Page 21.
(4) 45.1-51.3 inches. Turn to Page 50.

From Page 10

(3) This answer is incorrect. Return to Page 10.

From Page 81

(3) Right, we feel this is the best of the answers presented. Color coding and recessing are important, but shape coding is better and recessing may not be the best method to prevent accidental activation in every situation.

So, the SALV cockpit is coming right along. We've taken into consideration the audio and visual components within the cockpit and you've arranged these components so as to provide the best work space layouts possible. The job must be finished, right?....wrong! Remember the mission objectives for this fantastic piece of equipment. The SALV is a land, sea, and air vehicle. While you aren't in charge of designing these capabilities into the SALV, you want to insure that the man-machine interface is without major flaws. Consider the land operations of the SALV. You already know that the terrain is hilly and the SALV be able to reach speeds of 35 mph. Given these pieces of information, what do you think you need to consider next?

(1) Hypoxia, acceleration effects, and restraints. Turn to Page 20.
(2) Restraints, vibration, and dust effects. Turn to Page 17.
(3) Toxic fumes, G-forces, and vibration. Turn to Page 56.
(4) Noise, visibility, and hypoxic conditions. Turn to Page 94.

From Page 67

(2) High face validity is probably a good thing to have in any experiment, but this is not the point of external validity. Return to Page 67.

From Page 29

(3) The first question is too improbable to be correct. Return to Page 29.

From Page 53

(1) No lower and upper thresholds are presented in Table 3. Return to Page 53.

From Page 28

(3) Exactly right. Unless you consider human factors engineering at the beginning of system development, you will encounter problems.

If you follow specified procedures, and initiate HFE in the concept exploration phase, you'll be on the road to successful system development. But where can you find guidance for applying human factors data and principles to equipment design? MIL-STD-1472, 'Human Engineering Design Criteria for Military Systems, Equipment and Facilities,' provides such guidance. Let's take a closer look at that document.

The foreword of this standard presents an excellent overview. In part, it states that herein is established 'Human Engineering Criteria for Design and Development of Military Systems, Equipment and Facilities.' The ultimate goals to be achieved by this document are fourfold; namely, to:

(1) Achieve required performance by operator, control, and maintenance personnel.
(2) Minimize skill and personnel requirements and training time.
(3) Achieve required reliability of personnel-equipment combinations.
(4) Foster design standardization within and among systems.

The document is divided into three major areas: introductory material, general requirements, and specific requirements. The third of these dealing with specific requirements constitutes the bulk of this military standard.

The introductory material contains three sections (or paragraphs): (1) scope, (2) references, and (3) definitions. The scope more or less reiterates the foreword. Paragraphs 2 lists some of the more widely used specifications and standards. As you go about your job, it's important to know about these references. Paragraph 3 contains accepted definitions of terms used in this document. It is crucial for you to know exactly what these different terms mean.

The second major part of MIL-STD-1472 (Paragraph 4) contains general requirements for military systems. Use this section to answer the following question.

(GO ON TO THE NEXT PAGE)

From Page 36

You may have heard the slang term K.I.S.S. (Keep It Simple, Stupid). This really is a basic human factors principle. What is the technical term describing it and where can you find its definition?

(1) Simplicity of design, Paragraph 4.6. Turn to Page 33.
(2) Human engineering design, Paragraph 4.4. Turn to Page 57.
(3) Fail safe design, Paragraph 4.5. Turn to Page 87.

From Page 59

(1) This is a correct answer, but several others go with it. Return to Page 59 and choose another answer.

From Page 18

(1) These are products of the demonstration and validation phase, but they are not two stages in the acquisition process. Return to Page 18.

From Page 69

(1) Redesign falls outside of hazard analysis. Return to Page 69.

From Page 3

(2) Very good. OJT is widely used in the military and elsewhere.

Lesson 29 evaluated a number of training programs as to their validity. In addition, an important concept was introduced when discussing simulator training, namely fidelity. Can you remember what this term refers to?

(1) The degree to which a simulator reproduces in the training tasks the behavioral processes that are necessary to perform a job. Turn to Page 44.
(2) The degree to which a simulator represents the real world of the operational equipment. Turn to Page 19.
(3) Both of these answers are correct. Turn to Page 69.

From Page 7

(2) Man's reasoning ability is not severely affected. Return to Page 7.

From Page 70

(2) Well even half a flare would result in visual interference, we're afraid. This answer was thought of but rejected because of that interference. A small laser beam projecting straight up might not interfere, but it also might not be visible. Another sensory modality is more feasible. Return to Page 70.

From Page 53

(3) Right. You have learned to use this table quite well. Keep this military standard in mind for future reference--it will come in handy.

Before we drift too far away from vision, let's deal with another method HF specialists use optical aids to improve performance. Now, when using magnifiers to increase the degree of detection, do you think that the degree of detection is equal to the degree of magnification?

(1) It has never been determined if the two are synonymous or not. Turn to Page 91.
(2) Yes, increasing the magnification by five times also increases the detection by that amount. Turn to Page 26.
(3) No, because while magnification increases the size, it lowers the target brightness, lowers the contrast between target and background, and makes the image fuzzier. Turn to Page 72.

From Page 81

(2) This is a good answer, but it is not the one we feel is best. Return to Page 81.

From Page 96

(1) Very good.

The first of these stages (subsystem development test and evaluation) tests individual components and subsystems to determine if they meet the requirement for which they have been established. The human factors engineer can use these tests:

--To determine how well component or subsystem design conforms to good human engineering practice.

--To evaluate provisions for life support, escape, survival, and recovery of personnel when applicable.

--To determine the reliability and maintainability of components or subsystems.

--To identify skills that will be required by the personnel in the system. (Remember your task analysis lessons?)

--To evaluate and refine initial requirements for personnel and training.

--To determine whether equipment being developed for training meets performance or design specifications.

--To allow training specialists to become familiar with elements of the system so that they can design better instructional materials for later training programs.

So far, what you have been learning concerns development testing or DT. DT is done in the factory, in the lab, and on the proving ground. Its purpose is to demonstrate that:

(1) The design and development process is complete.

(2) Design risks have been minimized.

(3) The system meets specifications.

(4) When the system is introduced, it will be useful for the military.

Please remember that DT is not a one-shot affair.

(GO ON TO THE NEXT PAGE)

From Page 40

In addition to DT, there is also Operational Testing or OT. What is the difference between DT and OT?

(1) There is no difference in concept between DT and OT. The Army uses the term DT, while the Navy uses OT. Turn to Page 59.
(2) DT is primarily concerned with hardware design criteria, while OT is primarily concerned with personnel training requirements. Turn to Page 71.
(3) DT demonstrates hardware design effectiveness, while OT estimates whether the design can be used effectively. Turn to Page 78.

From Page 21

(2) It's true that no mention of seat belts is made in this paragraph, but in paragraph titled "Seat Belts" there is specific guidance; their use is not left to the discretion of the designer. Return to Page 21.

From Page 15

(3) You are correct.

It occurs to us that at this point in your training, the most effective learning (or refresher) tactic might be to present a checklist that summarizes some of the key concepts and rules of thumb to follow when dealing with control design. So, we did just that and put it in your supplement for Lesson 40.

Okay, we've made it through the first 20 lessons; now, it's time to move on to the next 20 lessons and deal with how the human fits into the system. Let's begin by dealing with a number of factors that are important aspects of any system; for example, system maintainability, which involves designing for effective and efficient maintenance. In this lesson, we discussed an important concept known as operational availability which represents the quantitative description of how often the system is working. Can you remember two key measures of operational availability? What are these measures and to what do they relate?

You remember that MTTR (Mean Time To Repair) is a measure of maintainability and MTBF (Mean Time Between Failures) is a measure of reliability. We bet you also remember that MTBF typically does not take into account human performance reliability, but only system reliability. You learned that to attend to the reliability of the hardware only results in solving only 50 percent of the total reliability problem. You also learned that human performance reliability information can be used to derive two measures of complexity. What are these two measures?

(1) Human limitations and capabilities. Turn to Page 93.
(2) Configuration and machine complexity. Turn to Page 78.
(3) Task and hardware complexity. Turn to Page 3.

From Page 60

(1) This is an excellent alternative but it isn't the only viable one. Return to Page 60.

From Page 53

(2) No lower and upper thresholds are presented in Table 3. Return to Page 53.

From Page 70

(3) The 'sidewinder' is a reality only because there are no interfering objects in the sky (such as our planes). On land, there are too many things other than the intended target that could attract a heat sensor. Return to Page 70.

From Page 33

(1) You're using data for the 5th and 95th percentile man. This is a common mistake. Reread Paragraph 5.6.1. Return to Page 33.

From Page 12

(2) What makes you say that? MIL-STD-1472 details quantitative data, whereas this specification speaks in more general terms. Return to Page 12.

From Page 73

(3) This is probably not going to be useful. The use of anthropometric data from customers will allow you to space walkways appropriately, but you don't know that the walkways are contributing to the problem. Return to Page 73.

From Page 38

(1) You're right in that this answer refers to functional fidelity, but there is another answer that is more correct. Return to Page 38.

From Page 31

(3) That's the answer we felt was most correct. The number of entry-exit doors could be adding to congestion, but not as much as the food item groupings. The replacement of food may be slow, but you haven't been told that. And, even if replacement were slow, it isn't the main cause of the congestion.

In Figure 38.1 you can surmise that 'our hero' in his rush to get back to work quickly, probably broke into the cafeteria serving line in order to obtain both the small salad and the dessert. Now, of course, he wasn't the only person who was doing this. Some people only wanted small or large salads or desserts and they all had to break through the hot food service line. In addition, our hero had to cross the entire facility one and a half times in order to obtain his purchases. That's too much!!

So, the arrangement of items is the major cause of all the congestion. By the way, how was that cause determined? One way we studied the problem was by recording the types of food items on each person's tray over a typical lunch period. Then, we determined the most frequent combinations of purchases. As a result of these observations, we found that:

(1) Forty percent of the customers wanted hot meals with or without a small salad and dessert.

(2) Forty-five percent of the customers wanted a short order; a prepackaged sandwich. Of those, 30 percent wanted a salad and dessert.

(3) Five percent just wanted either a drink, salad, or dessert; mostly just a drink.

This information indicates that about 13 percent of the people are following a pathway similar to our hero. However, some of these people entered through the other entryways and, therefore, have traversed the serving facility twice before checkout. Figure 38.2 gives you an idea of the confusion caused by having several entry paths; however, we feel that some of this will be rectified by a better item arrangement. In addition, the manager said he wanted all of these passageways to be available.

(GO ON TO THE NEXT PAGE)

From Page 45

We have an idea of what we consider to be a best new arrangement. Which of the following would you consider to be the best new sequence for arranging the food items?

(1) Short orders, sandwiches, cafeteria items, small and large salads, desserts, beverages. Turn to Page 19.
(2) Short orders, sandwiches, desserts, small salads, cafeteria items, beverages, large salads. Turn to Page 51.
(3) Short orders, salads, desserts, sandwiches, cafeteria items, beverages. Turn to Page 100.
(4) Beverages, desserts, salads, cafeteria items, sandwiches and short orders. Turn to Page 54.

From Page 33

(2) These data were correct before the 10 May 1978 change to this document was issued. Be sure you have all the applicable revisions of MIL-STD-1472. Return to Page 33.

From Page 59

(3) This is a correct answer, but several others go with it. Return to Page 59.

From Page 23

(3) This is the correct answer. The first thing you need to do is determine if a training program will solve the problem. Just because you are told by the client that this is what is needed, this doesn't make it so. Sometimes people do not really know the best solution to their problems.

Often, when a piece of equipment has passed hardware testing, it is considered to be 'perfect' in a sense. That is, it has the capabilities to fulfill all its functions and mission requirements as they were designed to be fulfilled. If its use is not effective, then too often the cause of the problem is attributed to the operators and users; in your case, it is attributed to the marksmen. When this occurs, training is usually the quickest solution offered. However, in the present example, trained infantrymen used the weapon and failed; expert marksmen also used the weapon and failed.

Now you have a dilemma.....a 'perfect' piece of equipment and 'perfect' operators, which result in mission failure. In answering the last question correctly, you indicated that determining if a training program was really needed should be your first step in solving the X-2001 problem. What should your first question be in determining whether training was needed?

(1) Identify the human performance requirements of the X-2001. Turn to Page 5.
(2) Obtain detailed descriptions of the capabilities and skills of both groups of test personnel. Turn to Page 61.
(3) Both of these go together and should be asked first. Turn to Page 69.

From Page 15

(4) No go, a correct answer is presented. Return to Page 15.

From Page 90

(3) This isn't right. There is certainly a need for having both documents. Return to Page 90.

From Page 73

(4) You should do this, but it isn't the first thing to be done. It is an important aspect of conducting this study, however. So keep it in mind. Return to Page 73.

From Page 86

(1) A low frequency bell doesn't have good noise penetrability, and a steady-state signal isn't a good attention getter. Return to Page 86.

From Page 90

(4) Right. We'd bet that you have one or the other documents in your command, depending upon whether you work with the Army or the Navy. We doubt whether you have both documents. Each document does have specialized information which refers to equipment used by that particular branch of the service.

Now, the next document to be discussed is the MOAT. MOAT was developed by Helm and Donnell of the Pacific Missile Test Center, Point Mugu, in October 1979. MOAT stands for Mission Operability Assessment Technique. As you can see from the title alone, this document addresses only operability. Hfteman and Hedge have a much broader range of system testing functions.

MOAT also differs from the other documents in that this document presents an evaluation methodology to assess how well an operator can use a system or subsystem to perform tasks within a mission context. The technique provides information on the degree of successful performance. The usual human engineering design criteria is presented as an all-or-none or pass-fail situation. MOAT, in general, assesses not the design features of equipment, but the workload of the operator as a result of the system (which includes the equipment, of course).

There is another document that also addresses the testing and evaluation of systems. HRTES has been developed by U. S. Army Research Institute for the U. S. Army Operational Test and Evaluation Agency. HRTES is a Human Resources Test and Evaluation System. It is designed to provide an adaptable system of procedures to be used in planning and conducting an operational test and system evaluation. The procedures will allow you to evaluate the causes of inadequate performance from the standpoints of training, human factors engineering, and manpower selection.

We find HRTES to be more general in nature than HFTEMAN or HEDGE. That is, the procedural steps used in HRTES could be applied to the testing concepts of HFTEMAN or HEDGE.

So far we have presented the purpose and stages of human factors test and evaluation. You have also learned about various documents which will provide you with the plans, methods, and procedures to enable you to conduct such tests and evaluations. Now we would like to introduce you to some equipment you will be using in your work as a human factors specialist. The human factors engineering field instrumentation package can be found on Pages 146-160 of your text supplement. Take a second to flip through this brochure. You may have already come into contact with some of the instruments contained in this kit.

(GO ON TO THE NEXT PAGE)

From Page 49

Page 152 of the instrument package brochure presents an equipment list. This list presents the topic area you may need to measure, along with the proper instruments to use for such measurement.

Suppose you were tasked with measuring the pollutants to be found in a specific area. Which piece or pieces of equipment would you select for this purpose?

(1) Scientific pollutants tester/monitoring gas sampler. Turn to Page 27.
(2) Aspirating psychrometer/universal gas tester. Turn to Page 18.
(3) Universal gas tester/monitoring gas sampler. Turn to Page 25.
(4) Universal gas tester. Turn to Page 64.

From Page 59

(2) This is a correct answer, but several others go with it. Return to Page 59.

From Page 33

(4) You've selected data based on 5th-95th percentile woman. Reread Paragraph titled "Anthropometry, General" and remember to account for the man. Return to Page 33.

From Page 46

(2) Very good. By placing the salads and desserts between the short order types of foods and the cafeteria line, you have satisfied both customers. You've decreased our hero's time in the serving facility by reducing the amount of walking he had to do.

In addition to the new layout, it might also be more convenient to have milk and beverages in two places rather than them separate. In so doing, you would create two traffic patterns which should serve most of the people without any point of contact, except when picking up salads and desserts. We feel that eventually those who want short orders will enter by the doors closest to the short orders and those desiring hot foods will enter by the other doors. The suggestions we've made are represented in Figure 38.3. It might also help to provide signs outside to direct the traffic through the proper doors.

Of course, there will still be people who want short orders and large salads, but other than using only one entry and exit to keep everyone in the same line, you can't solve the entire problem.

We've provided you with Figure 38.4. This represents the control room of a nuclear reactor. After the lesson, take a few minutes and see if you can't rearrange things so that a more efficient pathway can be found. You can see how important proper arrangement is for this system. If our hero had to run back and forth in the power plant control room, he wouldn't be as effective as he could be.

(GO ON TO THE NEXT PAGE)

From Page 2

(1) Indirectly, you are correct. But, this regulation does not apply to the entire DOD. Return to Page 2.

From Page 51

So, you've been involved in something other than the SALV project. However, SALV is the most important project in your active file, so we guess you'd better get back to it.

For the balance of this lesson you will be using TM 29-76. You should already have read this document and, therefore, you will be pretty familiar with the two types of human factors tests which were conducted. In this document, two systems were evaluated as a result of the evaluation. In which system would changes most likely be made and why?

(1) The communication control unit, because it is in the brassboard stage. Turn to Page 25.
(2) The communication control unit, because this system is a primary one for mission completion. Turn to Page 16.
(3) The mission control station, because of its importance to system effectiveness. Turn to Page 90.
(4) The mission control station, because it was only in the breadboard mock-up stage. Turn to Page 24.

From Page 88

(1) When you modify a traditional system, a systems analysis is by no means out of place, but it is more crucial elsewhere. Return to Page 88.

From Page 61

(3) You're right. Both of these glare devices are good examples of HFE input.

Glare is a visual example of bow man's physiological capabilities can be adversely affected and, thus, hinder successful performance. To reinforce the importance of accounting for man's physiological capabilities and limitations (as well as the various factors that affect these capabilities) when designing all aspects of a system, let's look at an auditory example. In many military situations, it is important to know the limits of noise detectability and nondetectability. If you'll recall, this information is included in MIL-STD-1474 (see Page 26). By looking at this table, you should be able to calculate how near to the sound a person has to be in order to be heard at a certain distance. Now, how loud must a 2,000 Hz alarm be to be heard 4,000 meters away?

(1) The alarm must be between 84 and 108 dB. Turn to Page 35.
(2) The alarm must be at least 100 dB, but not more than 110 dB. Turn to Page 43.
(3) The alarm must be at least 108 dB. Turn to Page 39.
(4) None of these choices are correct. Turn to Page 32.

From Page 56

(2) Very important, but to do this properly, you must first know what a task is. Try again. Return to Page 56.

From Page 79

(1) Exactly right. As stated in the DID, it serves as the principal means of substantiating the feasibility of required human performance, the accuracy of the personnel selection criteria, the adequacy of the training program, and the acceptability of the man-machine interfaces.

This review has been quite brief, but we hope it's achieved its objective; i. e., we hope that you are now more aware of where to look when you have questions. Be sure to keep these documents handy and check periodically to ensure that they are up-to-date. Most of all, be sure to consult the appropriate document whenever you are faced with a human factors problem.

The next lesson will review the major human factor organizations which are prominent today. You may be a member of one or more of them. Let's see where you fit in the overall scheme. See you when you begin Lesson 37. Turn to Page 57.

From Page 46

(4) This is just a mirror image of the existing layout. Return to Page 46.

From Page 67

(3) You're right. External validity deals with how much can be inferred from your results.

Okay, we're rapidly approaching the end of this course, and we'll wrap things up with a question and discussion on statistics. Descriptive statistics were examined in Lesson 33 where we spoke of measures of central tendency; such as mean and median, as well as measures of dispersion, such as range, and mean deviation. Our main concern, when working with descriptive statistics such as these, is to present our data in an understandable format.

In Lesson 34, we discussed statistical methods which allow you to describe the relationship between variables as scores and statistical methods which enable you to make inferences or generalizations about the data you have. Okay, we're getting ready to ask the final question in this lesson (and this course). In fact, this will be question number '430.' Are you ready? Here we go. In Lesson 34 we distinguished between two major types of inferential statistical techniques. What are they?

(1) Descriptive and inferential statistics. Turn to Page 92.
(2) Parametric and nonparametric statistical techniques. Turn to Page 80.
(3) Parametric and parsimonious techniques. Turn to Page 8.

From Page 24

(2) While the independent variable(s) may have been mentioned, this section is primarily used to show how the study was conducted and how the relevant variables were controlled. Return to Page 24.

From Page 97

(3) You're right. Task analysis provides information concerning these five system components.

Also, in Lessons 23 and 24, we discussed some major problems in the field of task analysis. What is the primary problem in this area?

(1) Having a standardized definition of what a task is. Turn to Page 85.
(2) Constructing adequate task inventories. Turn to Page 53.
(3) Determining human performance requirements. Turn to Page 58.
(4) All of these are the primary problem area in task analysis. Turn to Page 68.

From Page 9

(2) True, but not only this area contributes to poor performance. Return to Page 9.

From Page 34

(3) At speeds of 35 mph we wouldn't expect to have any G-force effects, would we? Return to Page 34.

HUMAN FACTORS ENGINEERING

LESSON 37: HUMAN FACTORS TEST AND EVALUATION

Well, you've just about made it to the end. You've been introduced to a myriad of topics on human factors engineering. You have followed the bittersweet story of LT Webster and have learned, together with Webster, what goes into human factors design of equipment. But how do you know if you've successfully completed your job? Off the top of our heads, we can give you two possible ways. We could wait until the system is used in the field. If it works, you are in good shape. A second and more viable means is through system testing. As you can guess from the title, human factors testing is the subject of this lesson.

In this lesson you will learn when to conduct testing and the purposes of HFE testing from a military perspective (AR 70-10) and from the perspective of professionals in the HFE field (Chapanis and Van Cott). Next, you will learn about the major types of HFE testing (DT and OT). Following this somewhat theoretical explanation, you will be provided with information about various HFE test and evaluation documents.

Before we get into any detail on HFE testing, we want you to take a moment and gather your thoughts. When do you think it's most important to conduct a human factors test?

(1) During prototype development. Turn to Page 82.
(2) During the preliminary design process. Turn to Page 76.
(3) When the system is in operation. Turn to Page 96.

From Page 37

(2) You're guessing. Look at Paragraph 4 in MIL-STD-1472 to get the answer. Return to Page 37.

From Page 69

(2) Very good. It's important to realize that a hazard exists; then you need to analyze it by breaking it down into its parts; and then recommend changes.

Now it's time to back up and talk in much more general terms. First, we'll deal with 'systems acquisition' concepts, and then touch on aspects concerned with systems analysis, task analysis, and trade-off analysis. But first systems acquisition dealt with the role of HFE in both the design process and the overall life-cycle process of a system. The acquisition process is composed of four major phases. Can you identify them (and in order, please)?

(1) Concept exploration, demonstration, and validation, full scale engineering development, production and deployment. Turn to Page 88.
(2) Demonstration and validation, concept exploration, production and deployment. Turn to Page 2.
(3) Production and deployment, concept exploration, demonstration and validation, full scale engineering development. Turn to Page 32.
(4) None of these answers is correct. Turn to Page 26.

From Page 61

(2) While glare shields are, indeed, an important example of HFE input, do you think they are the best and only example? Return to Page 61.

From Page 56

(3) This is really part of the systems analysis process. However, to do an adequate job here, you must be able to define what a task is. Try again. Return to Page 56.

From Page 76

(3) Right. This would be especially true of components not yet developed (e. g., training or selection programs).

If you look at Figure 37.1 on Page 136 of your supplement, you will find a graphic display of the various trade-offs involved in conducting tests and making changes to a system at the different stages of development. Not surprisingly, it costs progressively more to make HFE changes in later stages of development. Yet, changes recommended during later development are also more likely to improve system effectiveness, since they are based on more precise data. Unfortunately, the probability that the program manager will adopt recommended HFE changes decreases as the design becomes more defined.

Figure 37.1 also shows that the most cost-effective time to detect and correct human errors or substandard performance times is towards the end of the demonstration and validation phase. Why?

(1) Because you'll have to go through a lot of red tape if you try to make changes later. Turn to Page 37.
(2) Because the only other alternative involves upgrading selection and training, an expensive option. Turn to Page 50.
(3) Because design modifications are one-time costs. Turn to Page 46.
(4) All of these. Turn to Page 95.

From Page 41

(1) In the past, the Army and Navy have used different terms for similar concepts, but such is not the case with DT and OT. Both services use DT and OT to refer to two basic categories of testing. Now, which answer do you chink is correct? Return to Page 41.

From Page 15

(2) These aren't the only factors that must be considered. Return to Page 15.

From Page 24

(3) Right. When Berson and Crooks presented their analysis, they explained exactly who participated in the study and how the environmental variables such as temperature were measured. They also described clothing and personal and test equipment that were used.

The HFE test preparations part of TM 29-76 was presented to you so that when you conduct studies on the SALV project you'll have a model to use. Tables 9 and 10 report what the pilot and copilot are required to do (tasks) and the behaviors necessary to accomplish these tasks (subtasks). You learned about these topics in Lessons 23 and 24 which were about task analysis. Remember? During the earlier stages of systems development, these elements were defined in a conceptual manner. This test was conducted to determine if the pilot and copilot could, in fact, satisfy the known human performance requirements of the system.

In analyzing the study, Berson & Crooks reported their results and document the impact of existing problem areas on mission effectiveness. Suppose that you had run a similar study on the SALV. One of the major findings in this study can be found on Page 89 under conclusions C.2. Because your copilot and pilot shared part of an important panel subpart, they interfered with each other in operating the equipment. As TM 29-76 states, this confusion is 'expected to produce catastrophic failures.' What is your recommendation?

(1) Train operators so that they would coordinate their activities when using the shared panel. Turn to Page 43.
(2) Redesign the 'problem' panel so that only one operator uses it. Turn to Page 99.
(3) Redesign that panel so that no possible interference could occur between the pilot and copilot. Turn to Page 81.
(4) All these answers are viable alternatives. Turn to Page 11.

From Page 7

(4) Your answer is incorrect. Return to Page 7.

From Page 63

(4) You're right; all of these answers are important reasons why man's information processing limitations and capabilities must be recognized.

Problems often arise, however, when man's abilities are viewed in the light of 'absolute maximum performance levels' when designing the man component into a system. By focusing on these maximum standards, no flexibility is designed into the system to account for various environmental or job-related variables that can reduce this level of performance.

For instance, in terms of visual performance, glare (caused by direct or reflected light that is much greater than what the eyes can adapt to) can seriously detract from successful completion of the task. Thus, such visual factors need to be taken into account when designing a system.

Now, can you remember a good example of how human factors specialists take glare into account when designing equipment?

(1) Red goggles are often used to block out the glare and allow the eyes to stay dark adapted. Turn to Page 77.
(2) Glare shields are often designed into the system to block glare and maintain visibility. Turn to Page 58.
(3) Both glare shield and sunglasses are good examples of the input the human factors specialist has in system design. Turn to Page 53.
(4) Sunglasses with high-quality polarizing filters are often used by pilots to cut down on the amount of glare encountered. Turn to Page 97.

From Page 47

(2) Good, but not complete. That might be helpful for identifying any effects of RVs, but it's not the answer here. Return to Page 47.

From Page 78

(1) You're right. We have only provided information on subsystem or system reliability. We haven't conducted all HFE tests yet. Well, in a way, all of these were right, but not enough to be considered the right answer. We have touched on performance reliability, but only touched on it. More HFE testing is needed to examine the man-machine interface in greater detail.

When we start talking about HFE tests, to what do you think we're referring?

(1) Personnel qualification tests. Turn to Page 19.
(2) Personnel selection testing. Turn to Page 21.
(3) Neither of these is correct. Turn to Page 9.

From Page 8

(1) Exhaust fumes could be the problem, but what about vibration? Return to Page 8.

From Page 76

(1) It may be easier to evaluate a system using a mock-up, but there are other ways of doing it. Return to Page 76.

LESSON 40: COURSE SUMMARY

The purpose of this lesson is to summarize some of the major and important points made during each of the preceding 39 lessons. Because of the scope of this course, any detailed summary and review would take you almost as much time to complete as has the entire course. Unfortunately, we won't be able to review everything we feel is important in the human factors area, but hopefully, what is presented will reinforce those concepts for you, as well as initiate the recall of related issues in the field.

In the early part of this course, the man-machine interface was examined in light of man's capabilities and limitations; the point was made that these abilities must be taken into account by the HF Specialist when designing systems that incorporate man as an information processing component. Regardless of whether we are talking about an information system, it is critical that man's limitations are considered. Why do you think this is so?

(1) The cost to the military of having large numbers of people unable to make quick and accurate decisions (due to processing overload) can be severe. Turn to Page 88.
(2) The increased complexity of modern day equipment has placed new and greater demands on the operators of these high technology systems. Turn to Page 72.
(3) The time and resources required to maintain system or subsystem operations often will take away from other important responsibilities placed on the operator. Turn to Page 83.
(4) All of these answers are correct. Turn to Page 61.

From Page 9

(3) True, but not only this area contributes to poor performance. Return to Page 9.

From Page 50

(4) Only half correct. There are two types of equipment you can use in measuring pollutants. Return to Page 50.

From Page 14

(1) Maintainability is, of course, right up your alley, but as an HFE Specialist you will be concerned with other things as well. Return to Page 14.

From Page 97

(2) You're correct in that this is an important task analysis function, but is it the only function? Return to Page 97.

From Page 12

(4) We haven't even discussed MIL-STD-1474 in this lesson. Return to Page 12.

From Page 97

(4) This is not the only purpose of task analysis. Return to Page 97.

From Page 10

(2) You're right. A general decline in performance occurs over time, with the largest decline occurring during the first 30 to 60 minutes on watch.

So far we've covered a number of areas where man's capabilities and limitations are of concern to HF specialists. Now, before we move on to a coverage of the material in the second 20 lessons, let's touch on some important concepts dealing with controls and displays.

In Lesson 9 you learned about a number of different types of visual displays, both quantitative and qualitative. A good bit of time was spent discussing an oft-used type of visual display-namely, representational displays. We mentioned two basic types of representational displays, inside-out and outside-in. Which of the following statements best matches the name of the display with an explanation of that type of display?

(1) When the surrounds move but the object remains stationary, you are using an outside-in display; but when only the object moves, you have an inside-out display. Turn to Page 77.
(2) When the pictured object moves, but its surroundings are stationary, you have an outside-in pictorial display; and when the surroundings move, but the object is stationary, you are using an inside-out display. Turn to Page 15.
(3) When both the object and surrounds move, you have an inside-out display; and when only the surrounds move, you have an inside-out display. Turn to Page 83.
(4) When nothing in the display moves, you have an upside-down display; and when everything moves, the display is called a contact analog. Turn to Page 91.

From Page 85

(3) Very good. ROC or TLR is the one factor of utmost concern, because it states the minimum essential operational capabilities, and technical, logistical, and cost information needed to initiate full scale development.

Well, we've got two questions to go, and still need to talk about statistics, experimental design, and psychophysical methods. Let's take these topics in order of appearance in this course, which means Lesson 30 comes first--psychophysical methods. This was the first of the five lessons to deal with experimental methodology and statistical techniques. If you'll remember, psychophysical methods are concerned with the relationship between stimulus intensity and sensation, or the perceived level of stimulation. And the purpose of these methods is to provide procedures for determining thresholds.

The two lessons that followed (Lessons 31 and 32) were concerned with experimental design, and we touched on things such as different ways to classify variables and different types of research methods. A good deal of time was spent in Lesson 31 examining the various types of research methods, be they theoretical or empirical. The majority of the lesson was spent discussing this second type of research, breaking it down into observation, correlation, or experimentation.

Lesson 32 deals more directly with specific problems found in empirical research and how to overcome these problems by controlling your relevant variables (be they subject, sequence, or situational RVs). Then, some time was spent dealing with internal and external validity as it relates to experimental design. When we talk about the internal validity of an experiment, we are addressing ourselves to the issue of whether our experimental results can be attributed confidently to the independent variables manipulated by the experimenter. Now, when moving from internal validity to external validity, one is moving from the mechanics of design to what?

(1) The mechanics of face validity. Turn to Page 27.
(2) Presenting a good external idea to your peers of what your experiment's trying to evaluate. Turn to Page 34.
(3) The ability to generalize from your results. Turn to Page 55.

From Page 28

(1) AR 602-1 doesn't mention a simulation phase. Return to Page 28.

From Page 56

(4) All of these are important, but they are not all one primary problem. The first step in conducting a task analysis requires that you are able to define what a task is. Return to Page 56.

From Page 38

(3) Very good. Representation refers to physical fidelity, while reproduction refers to functional fidelity.

Another important input to any system is a safety analysis, which is concerned with understanding why accidents occur and how they can be prevented. In Lesson 27 we described an accident as an event or occurrence which is both undesirable and unexpected; result from faulty equipment or inadequate performance by the human involved in the system. You may be a member of a safety team at one time or another. Using a systems approach, you will be called on to conduct hazard analysis. Do you recall the three parts of a hazard analysis? Which of the following best describes this process?

(1) Analysis, evaluation, redesign. Turn to Page 37.
(2) Analysis, evaluation, recommendation. Turn to Page 58.

From Page 47

(3) Incorrect, the human performance requirements need to be identified first. Return to Page 47.

From Page 5

(1) You've done well. The problem with the X-2001 was that the human couldn't see the target once the rocket entered his field of vision; the flare blocked out anything in front of it from the marksman's view. All the training in the world couldn't improve the situation.

Now we need to think of a possible solution to the problem. We don't know which answer is right. While some of us are hardware engineers, others of us are not, and we don't know what capabilities hardware engineers have at their disposal. However, we do have an idea as to which answer is most feasible from a human point of view, so that's the one we've chosen to be correct. Okay, what would you suggest as an improvement?

(1) Make the X-2001 programmable so that after the target distance was set, the rocket would activate an auditory signal when it had traveled that distance. Turn to Page 74.
(2) Put the flare only on the upper portion of the rocket so that the marksman could still see the lower part of his target. Turn to Page 38.
(3) Have a heat sensor attached to the rocket so it would detonate when it reached the target; somewhat like the heat-seeking missile, the 'sidewinder.' Turn to Page 43.

From Page 6

(3) You're right in that 3.2.2.1.1 deals with mock-ups, but you are waiting too long in the acquisition cycle to use it. Look at the first sentence of this paragraph and then try another answer. Return to Page 6.

From Page 41

(2) The DT part was correct, but OT has more than training requirements as a focus. Return to Page 41.

From Page 30

(2) If the displays were located between the pilot and navigator, the pilot would have to turn away from his own display area. Isn't the navigator typically seated away from the pilot? Return to Page 30.

From Page 97

(1) You're incorrect. Return to Page 97.

From Page 39

(3) Very good.

Okay, so far we have moved from a general discussion of man's information processing capabilities and limitations to several practical examples of how HFE specialists handle factors that affect these capabilities and limitations. Now, let's talk about several other characteristics of man that must be taken into account when designing a system. If you'll remember, way back in Lesson 6 we talked about anthropometry, the 'science' of dealing with the measurement and physical features and functions of the body. Man's physical dimensions are important aspects of any man-machine interface and must be considered very early in the design stages of the process.

In Lesson 6 an important design principle used most often by the military is referred to as 'designing for the adjustable range.' In the military services, what are the general design limits imposed when designing for the adjustable range?

(1) Design and sizing specifications for equipment insure that at least 90 percent of the male and female user population will be accommodated. Turn to Page 83.
(2) In the military services, design limits are based upon a range from the 5th percentile female to the 95th percentile of male values. Turn to Page 7.
(3) Design limits are based upon a range from 0 percentile male to the 90th percentile male. Turn to Page 85.
(4) All of the answers are correct. Turn to Page 26.

From Page 63

(2) While it's true that as technological advances are made, increasing demands are placed on the operators of these technically sophisticated systems, there is a better answer listed here. Return to Page 63.

From Page 98

(2) Good. These two sources have a wide range of anthropometric information.

Well, let's take a breath and recap for just a bit. You've been involved with the initial justification of this new weapon system. In its conceptual development phase you've aided the team by ensuring that the components within the system are designed so as to facilitate maintenance. In addition, you've been in on the ground-floor of the cockpit design. By using your knowledge of anthropometry, you've made certain that the operators of the SALV will fit the cockpit.

Since you have gained an awareness of human factors engineering, you have also noted that it can be applied to other sophisticated areas than weapons. In fact you go to the cafeteria and find the traffic congestion acute.

You ask the manager if you can conduct a study on the traffic flow problem. He is glad to get your help. Now the first thing you need to do or get is?

(1) Diagram of the facility so a flow pattern can be established. Turn to Page 31.
(2) Conduct a task analysis of the kitchen staff to see how they contribute to the congestions. Turn to Page 21.
(3) Customer anthropometric data to see if counters are the appropriate height. Turn to Page 44.
(4) Interview customers to get user opinions about the cause of the congestion. Turn to Page 48.

From Page 7

(3) You're wrong. Return to Page 7.

From Page 70

(1) We thought this was the most feasible answer too. We also think that this is within the realm of reality for hardware development, given that we do have radar and other similar devices.

Well, you've come to the end of the road, so to speak. You've worked on several problems and successfully applied your newly acquired human factors knowledge in their solutions.

Now, a few words of advice. This course was designed to introduce you to and familiarize you with Human Factors Engineering. It was not meant to qualify you as a Human Factors Engineer nor be the source of answers to all your problems. You aren't expected to memorize all the data to which you've been exposed. Come back to lessons in the future as you need them. Turn now to Page 63.

From Page 3

(1) This is an important training method, but not as widely used as the correct answer. Return to Page 3.

From Page 79

(2) HEL TM 29-76 gives examples, but we're looking only at DI-H-1334A. Return to Page 79.

From Page 98

(1) Well, you are half right. TM 29-76 is a useful reference for testing, not for anthropometric data. Return to Page 98.

From Page 86

(4) Well, this is correct, but there are other correct suggestions as well. Return to Page 86 and choose another answer.

From Page 3

(3) This is an important training method, but not as widely used as the answer we're looking for. Return to Page 3.

From Page 57

(2) Very good. The preliminary design process is the best and most important time to conduct a human factors test. Theoretically, the Development Testing (DT) I time frame is very important. But often a contractor will have only components available for DT I testing, not the whole system. Therefore, practically speaking, it is DT II that is most important for the DOD HFE specialist.

As we go through this lesson, you'll see that there are many factors which intertwine with testing.

The Department of Defense is quite specific in its requirements for system test and evaluation. DOD Directive 5000.3 (test and evaluation) indicates that it is essential that developmental and operational test and evaluation be accomplished in order to ensure that the systems introduced into service meet the defined operational requirements and are suitable for service use. They must begin as early as possible and continue throughout the system acquisition process in order to reduce acquisition risk and increase military worth.

Although this directive indicates a need to begin as early as possible, can you think of any disadvantages to an early start? What are they?

(1) You can't really evaluate a 'system' until it is at the mock-cap or similar stage. Turn to Page 62.
(2) It is not cost-effective to make changes early in the development cycle. Turn to Page 84.
(3) It is difficult to gather valid data in early stages. Turn to Page 59.

From Page 61

(1) While it's true that red goggles are a good example of HFE input into maintaining human performance, the goggles are important for dark adaptation, but not for glare. Return to Page 61.

From Page 66

(1) You've mixed up the types of displays. Return to Page 66.

From Page 88

(3) If you wait until a prototype has been developed, chances are you'll be in a lot of trouble. Return to Page 88.

From Page 41

(3) Right, DT has as a focus design criteria, while OT zeroes in on operational effectiveness and suitability.

Operational tests and evaluations are performed on operational models and are concerned with the use of the system rather than its design. The human factors engineer uses OT data:

--To determine operational difficulties with the system and to identify ways to improve deficient products or processes.

--To determine the operational usefulness of the system and to develop effective methods and standards.

--To refine maintenance requirements in terms of personnel skills and training and to establish performance standards for carrying out maintenance tasks.

--To collect data on organizational and personnel skills and on training to refine requirements established earlier in the program.

--To evaluate the adequacy of the manning structure, the table of organization, and the training program.

--To provide final training for operational crews and to integrate the entire system into the framework of existing systems and operations.

Which of the following will we be able to define, once this series of tests is conducted?

(1) None of these. Turn to Page 62.
(2) System validity. Turn to Page 24.
(3) System reliability. Turn to Page 87.
(4) Performance reliability. Turn to Page 16.
(5) All of these. Turn to Page 100.

From Page 42

(2) This choice contains two hardware selections. This represents only half the information. Try again. Return to Page 42.

From Page 6

(2) Exactly right. Paragraph 3.2.2.1.1 is meant to be used at the earliest practical point....'

Before we continue examining these documents, let's examine a little more closely the subject of contractor requirements. In addition to the specific data presented in a contract, there are usually references made to other material. When you deal with human factors engineering research, development, and implementation, these references will include a series of data item descriptions (DIDS). Turn in your supplement to Page 108. Starting on this page you'll find DID DI-H-7051. The following pages contain DI-H-7052 through DI-H-7059. These descriptions detail requirements as broad as an overall Human Engineering Program Plan (DI-H-7051), as general as a Human Engineering Progress Report (DI-H-7059), or as special as DI-H-7058 (HE Test Report). You'll need to be familiar with these DIDS as you begin to work with government contractors.

Your next document is MIL-STD-1474, 'Noise Limits for Army Materiel.' If you look at the foreword, you'll see the definitions of three types of noise criteria: hearing damage-risk criteria (DRC), hearing conservation criteria, and materiel design standards. As you thumb through this standard, you'll see that it is similar in format to several you've already examined. It contains references, definitions, general requirements, and detailed requirements. Since noise was the subject of an entire lesson, little else needs to be said at this point. Just be sure you're familiar with the data available in MIL-STD-1474.

The final military document we need to examine in this lesson is HEL Technical Memorandum 29-76, 'Guide for Obtaining and Analyzing Human Performance Data in a Materiel Development Project.' Take a moment and read the background provided on page 5 and the first paragraph of page 6. As you can see, the value of human factors engineering is well recognized by the Army. It should be obvious to you that the thrust of this report concerns the use of Data Item 1334A (now renamed DI-H-7058). This DID (Data Item Description) is presented in its entirety. How does this document fit with those we've already discussed?

(1) It provides you with the background to assure that all previous specifications and standards have been applied properly. Turn to Page 54.
(2) It gives examples of how to test to see that HFE principles have been applied. Turn to Page 75.
(3) Both of these are correct. Turn to Page 94.

From Page 55

(2) You're right.

Well, well, well. You've done it. You've actually made it through 40 long, tough lessons. But we think you'll agree that it was well worth the time and effort. Way back in Lesson 1, we introduced you to the field of human factors engineering and the idea that it deals with keeping people in mind when systems are being designed. We also presented the major aim of human factors engineering-maximizing effectiveness through the enlightened use of humans. We talked about how this can be done only if the human factors specialist concerns himself/herself with the health, safety, comfort, acceptance, and performance of individuals.

As you begin (or continue) your work as a human factors specialist, you may need to call on others in the field for help. If so, get a copy of the 'Directory of Researchers for Human Research and Development Projects' and open to Section 10. You'll find many names you can go to for assistance.

We hope that these ideas have become quite apparent to you now, and that you've become somewhat familiar with the basics of human factors engineering. We've enjoyed chatting with you throughout this course, and various lessons can be used as good 'mini refresher courses' as the different problems and topics we have discussed present themselves in the course of your work. Once again, we'd like to say it's been a pleasure talking with you, and we hope that your awareness of human factors has been sharpened.

Good luck.

From Page 30

(1) Right, the first priority in designing individual work places is directed toward the placement of primary visual displays.

Questions concerning the appropriate level of illumination, visual flicker, and the legibility of display symbols need to be answered when designing the display itself. After it has been appropriately designed, the display should be fit into a layout configuration which is easily discernible and accessible.

Now let's consider the design of controls. How would you design primary controls to minimize the possibility of confusing these controls with other controls or with each other?

(1) Shape code the controls; group displays together for easy check-reading; and provide adequate spacing between the controls. Turn to Page 92.
(2) Color code the controls; provide recessed controls to prevent accidental activation; and sequence the controls from left to right. Turn to Page 39.
(3) Shape code the controls; provide adequate spacing between controls; and group associated controls together. Turn to Page 34.

From Page 60

(3) This is an excellent alternative but it isn't the only viable one. Return to Page 60.

From Page 57

(1) Testing can be conducted at this point, but it is more important to test at another phase of system development. Return to Page 57.

From Page 18

(3) These are products of the full scale development stage, but not the stage themselves. Try again. Return to Page 18.

From Page 17

(1) When you considered vibration, you took into account one of the results of vibration.....motion sickness. So this answer isn't correct. Return to Page 17.

From Page 85

(4) Your answer is incorrect. Return to Page 85.

From Page 63

(3) You're right in assuming that highly complex systems tend to impose numerous information processing requirements on the operator. However, this answer is not the only correct answer. Return to Page 63.

From Page 72

(1) While it's true that the military generally designs to accommodate 90 percent of the population, you have not specified the range. Return to page 72.

From page 66

(3) When you have both object and surrounds moving, it's called a contact analog. Return to Page 66.

From Page 85

(1) Safety, indeed, does weigh heavily in any decision process, and you will not see it compromised very often. However, there is a high priority parameter. Return to Page 85.

From Page 76

(2) You've got it backwards. If you have enough data, make a change at an early stage--that's when it is more cost-effective. Return to Page 76.

From Page 4

(1) This is an important consideration for human factors engineering, but in this case, it would only be considered after you have designed the cockpit so that the operators fit into it. Return to Page 4.

From Page 3

(4) This is an important training method, but not as widely used as the correct method. Return to Page 3.

From Page 56

(1) You are right. Often different agencies and people confused the terms task, subtask, and task element. Once you have defined what a task is, the next major job is to construct a task inventory which lists all human performance requirements in some systematic way.

Finally, let's get around to talking about trade-off analysis. If you'll remember our discussion, we emphasized that since our resources are not unlimited, we, as designers, are restricted as to what can be developed. If no limits were place on our manpower availability, money, and technological input, nothing would be impossible. However, we're afraid this is not the case, and if you'll recall, various methods and decision processes involved in trade-off analysis were presented. Throughout this lesson, however, one parameter was considered to have a higher priority. Can you remember what that parameter was?

(1) Safety. Turn to Page 83.
(2) Life-cycle costing. Turn to Page 97.
(3) Required operational capability (ROC) or top level requirement (TLR). Turn to Page 67.
(4) All of the above. Turn to page 82.

From Page 72

(3) You are incorrect. Not only does the adjustable range in this answer not include females in the measurement, but also, it does not represent the correct range of scores. Return to Page 72.

From Page 29

(2) You're right. First you want to ensure the operator's auditory safety. Then you can determine how the speaking level is being interfered with.

In addition to the correct answer above, the question on warning signals was also important. We wonder how you would solve the problem presented in Item 1. Would you require headgear which would protect the crew and still allow oral communication? It seems there are a variety of ways this problem could be attacked. The solution that eventually is okayed depends upon the costs involved and how effective the solution is in leading to mission completion. For example, muffling the noise source may be costly. However, what if that noise can also be heard by an enemy? Sometimes noise is desirable: to scare the enemy. If, however, you don't want the enemy to know you're around, noise becomes an enemy. Then the mission, as well as the crew's hearing, is in jeopardy. If the noise were apparent only inside the cockpit, maybe protective headgear would be an efficient, effective, and inexpensive solution.

Suppose for a moment that the SALV was an established system. After 2 years in service, you get a call one day from your division chief. You are instructed to change a warning system within the cockpit. The present system has a series of flashing red lights which are activated when there is an engine malfunction. You are going to replace that visual system with an audio one (a beeping buzzer). What should you do?

(1) Use a low frequency bell instead of a buzzer and use a steady-state rather than an interrupted signal. Turn to Page 48.
(2) Test the signals to be sure they are detectable and keep the visual system with the new one in order to help people get accustomed to the audio one. Turn to Page 23.
(3) Two of these answers are correct. Turn to Page 30.
(4) Make sure the new signal isn't the same as an existing signal used for other purposes and use a frequency range between 500 and 3,000 Hz. Turn to Page 75.

From Page 37

(3) You're guessing. Look at Paragraph 4 of MIL-STD-1472 to get the answer. Return to Page 37.

From Page 78

(3) As often defined, 'system reliability' is only a combination of the reliability of the hardware components. But a human factors engineer knows better; it should also include the performance of the soldiers who operate and maintain the hardware. Return to Page 78.

From Page 31

(1) You've read more into the situation than it deserves. We didn't provide any information concerning the food service. Return to Page 31.

From Page 58

(1) You're quite right. The acquisition cycle moves in just such a fashion.

OK, we've moved through the phases of acquisition from concept exploration to production and deployment. Now, let's talk about what's involved in the process of systems analysis. In Lesson 22 we were exposed to some of the common techniques used when conducting a systems analysis (requirements analysis, functions analysis, task analysis). In addition, some of the roadblocks you'll encounter were presented, as well as how to avoid them. Also, we discussed when the use of system analysis was most important. Can you remember which of the following is the most important use for systems analysis?

(1) To help modify traditional systems. Turn to Page 52.
(2) To aid in developing a new system. Turn to Page 97.
(3) To help test a prototype. Turn to Page 77.
(4) All of these answers are extremely important uses for systems analysis. Turn to Page 28.

From Page 63

(1) The manpower and machinery costs that result from remaining ignorant on the issue of information processing is severe. However, other problems result as well. Return to Page 63.

From Page 9

(4) Very good. These are all areas which can result in inadequate performance. Most of the documentation to be discussed will have human factors and design as focal points, but this is not the only cause of less-than-adequate performance.

If you haven't been convinced of the need for this testing, the following quote from Howard (1976) should bring home the point. He reported that 50 to 70 percent of all failures in major weapons and space systems are human-initiated, placing 'human error ahead of design error, component unreliability, and lapses in quality control in manufacturing...'

Now you need to be aware of the numerous publications which pertain to test and evaluation. HFTEMAN, MOAT, and HEDGE are the names of three test and evaluation documents published by government agencies. You will learn what each is about in the remainder of this lesson. We will also provide you information on one other publication: HRTES.

HFTEMAN stands for 'Human Factors Test and Evaluation Manual.' It was published in October 1976 by the US Navy Pacific Missile Test Center, Point Mugu, California. HFTEMAN comes in three volumes: Volume I is a data guide; Volume II provides support data; and Volume III is devoted to methods and procedures. This document was developed to assist the Navy and Marine Corps T&E personnel in the evaluation of human factors aspects of weapons systems, equipment and facilities.

HFTEMAN provides a step-by-step procedure to be followed in evaluating and/or testing various equipment classes. It provides information on how to conduct tests of operability, maintainability, habitability, transportability, portability/usability, and erectability.

(GO ON TO THE NEXT PAGE)

From Page 89

HEDGE is the Army version of HFTEMAN. HEDGE stands for Human Factors Engineering Data Guide for Evaluation. This document was published in January 1978 by the US Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland. The format of the manual is similar to that of HFTEMAN, and the types of tests to be conducted are the same. Why would one service branch duplicate the documentation of another?

(1) To ensure the availability of the material to its own personnel. Turn to Page 30.
(2) To tailor the information to its own particular systems and equipment. Turn to Page 30.
(3) Neither of these answers is correct. There is no logical need for such duplication. Turn to Page 48.
(4) Both of these answers are correct. Turn to Page 49.

From Page 16

(2) We said to take a quick look at the document, but not that quick! Return to Page 16 and select another answer.

From Page 52

(3) Right system, wrong reason. The question refers to the likelihood of change and, while this station may be important to system effectiveness, change is easier and, therefore, more likely because of the developmental phase of acquisition in which the station was. Return to Page 52.

From Page 17

(3) We probably never cover every eventuality. We just hope to improve the situation by considering as many eventualities as possible. Return to Page 17.

From Page 39

(1) It has definitely been determined that the degree of detection is not equal to the degree of magnification. Return to Page 39.

From Page 66

(4) You're way 'off-base' here. Maybe if you stood on your head you could call it an upside-down display. Also, although contact analog is correct, that wasn't part of the question. Return to Page 66.

From Page 81

(1) This question asked about controls, but this answer has one choice dealing with displays. It's a good suggestion but inappropriate to the question. Return to Page 81.

From Page 15

(1) These aren't the only environmental factors which must be taken into account. Return to Page 15.

From Page 55

(1) These are broad statistical categories that go beyond inferential statistical techniques. Return to Page 55 for another answer.

From Page 8

(2) Noxious substances could be the problem, but what about vibration or other exhaust fumes? Return to Page 8.

From Page 24

(4) The sequencing of test materials is not presented in this section. Return to Page 24.

From Page 42

(1) Well, you have learned about limitations and capabilities throughout the course, but are these measures of complexity? No, we learn about limitations and capabilities 'from' indices such as measures of complexity. Try again on Page 42.

From Page 79

(3) Your answer would be correct if the question involved TM 29-76, but we asked about DI-H-1334A. Return to Page 79 and select another answer.

From Page 31

(2) This is a very plausible answer, but we feel there is a better one. Return to Page 31.

From Page 34

(4) Hypoxic conditions are the result of lack of oxygen. Nothing in this situation indicates that oxygen would be scarce. Return to Page 34.

From Page 59

(4) Right. By making changes in the experimental prototype stage (concept exploration), you have limited your costs by redesigning before the hardware has actually been built. The cost is a one-time cost. Later it becomes more difficult for a change to be accepted (red tape, if you will) and if a change must take place, it will usually involve people rather than the hardware.

Thus far we've discussed test and evaluation assuming you knew why it was done. Let's review the major purposes of HFE test and evaluation.

The following purposes of HFE testing are taken from Army Regulation 70-10 'Test and Evaluation During Development and Acquisition of Materiel.' This document states that testing is conducted:

(1) To see how well (how validly) the materiel system meets its requirements, both technical and operational.

(2) To provide data to assess developmental and operational risk for decision making.

(3) To determine that faults found in previous testing have been corrected.

(4) To insure that all critical issues which are to be resolved by testing have been considered.

AR 70-10 states that all testing (from the initial mock-up to the completed system) is of interest. Another way of stating the AR 70-10 purpose is to say the HFE tests and evaluations aim to improve the quality of design decisions. Early in development when the various subsystems are being developed, decisions regarding this design must be made. Systems testing helps in this process by providing information to improve the quality of decision making.

Secondly, test and evaluation helps to integrate hardware and personnel. This sounds like a major goal of human factors engineering in general, doesn't it? Since the discipline has not yet reached perfection, we are unable to forecast precisely the best ways of integrating man and machine. Therefore, the best way to validate a design is by 'trying it out.'

The third purpose of test and evaluation is to identify design deficiencies early. This has already been explained above and is presented graphically in Figure 37.1.

(GO ON TO THE NEXT PAGE)

From Page 95

Chapanis and Van Cott have detailed human factors objectives in the various phases of system development and testing. A synopsis of this information is provided below.

The major emphasis of system testing is found in the hardware subsystem. As human factors engineers, we are concerned with this subsystem as it impacts personnel. Therefore, our interest in hardware test and evaluation is twofold: (1) we must make certain that human engineering principles are applied to hardware design; (2) we can use data derived from hardware testing to test our personnel.

There are three stages of hardware test and evaluation. They are:

(1) Subsystem development test and evaluation
(2) System development test and evaluation
(3) Operational tests and evaluations

Why do you think these three stages were listed in this order?

(1) Because it is necessary to study the parts of a system before either the system itself or the operability of the system can be evaluated. Turn to Page 40.
(2) Because the components of a system are more important to test and evaluation issues than either the system or its operators. Turn to Page 28.
(3) Because operations tests are the most difficult to perform and are, therefore, conducted last. Turn to Page 4.

From Page 57

(3) Testing can be conducted at this point, but it is more important to test at another phase of system development. Return to Page 57.

From Page 88

(2) Well done. When working with new systems there are so many unanswered questions that unless a good systems analysis is conducted, the probability of developing a good system is quite low.

After systems analysis you learned about task analysis. In fact, we thought it to be so important that two whole lessons were devoted to task analysis. What was the aim of task analysis explained to be in Lesson 23?

(1) To provide information dealing with performance appraisal. Turn to Page 71.
(2) To provide information that will aid in the design of the system. Turn to Page 64.
(3) To provide information for five system components: design, training, test and evaluation, manning, and workload. Turn to Page 56.
(4) To provide information that will aid in the test and evaluation phase. Turn to Page 65.

From Page 61

(4) While it's true that sunglasses are used to reduce glare, there is another answer that is more appropriate. Return to Page 61.

From Page 85

(2) Costing is quite flexible and often changing, so this cannot be the correct answer. Return to page 85.

From Page 4

(3) Very good. Before you attend to any other considerations, you would want to be sure that the cockpit fits the people who will use it.

It is extremely important to make sure that the physical surroundings are designed to accommodate the range of body dimensions possessed by the potential users of the system.

Remember, in today's military we have female as well as male troops. So, the 5th to 95th range must include female data if you expect female users. In some situations (like the chin strap of a helmet, remember?) your design must be twofold: 5th to 95th for male user equipment and 5th to 95 for female user equipment. In other cases (such as the cab of a truck) you will need to use the broadest (5th to 95th) range. That is, the 5th percentile female to the 95th percentile male data.

Now the next set of questions that you must consider concerns the basic structural dimensions, as well as various function dimensions of the work place: How high from the floor should the seating be? How far from the controls should the seating be in order to allow the operator to grasp the various knobs, switches, and levers without strain? How high should work surfaces be for seated personnel? For standing personnel? You get the idea. What two sources will aid you the most in providing answers to the above questions?

(1) TM 29-76 and MIL-STD-1472. Turn to Page 75.
(2) MIL-STD-1472 and MIL-HDBK-759. Turn to Page 73.
(3) RFP and ROC. Turn to Page 32.

From Page 6

(1) Because a system is 'automatic' does not mean that human interface is not required. Return to Page 6.

From Page 60

(2) This is an excellent alternative, but it isn't the only viable one. Return to Page 60.

From Page 30

(3) 60 degrees below the horizon isn't what you want to aim for; the normal line of sight is about 15 degrees below the horizontal. Return to Page 30 and select another answer.

From Page 5

(3) This isn't necessarily so. That aspect of the human's physiological visual capabilities was taken into account. You're sighting on the target, not tracking the rocket. When the rocket and target are together, you shoot. Return to Page 5.

From Page 8

(3) Vibration could be the problem, but what about fumes? Return to Page 8.

From Page 78

(5) We really haven't looked at the operator/maintainer in any depth, and that immediately rules out several choices. Return to Page 78.

From Page 46

(3) While this helps our hero, it creates a problem by having hot meal customers break into line for their salads. There must be a better way. Return to page 46.